ROTARY TUBULAR KILN

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application claims priority from German patent application Serial No. 10305147.3 filed on February 8, 2003.

FIELD OF THE INVENTION

The present invention relates to a rotary tubular kiln with a longitudinal seal. The seal extends within a bowl-shaped heating tunnel surrounding a rotating tube which can be heated from the exterior of the tube. The present invention also relates to a method for the production of the noted longitudinal seal.

BACKGROUND OF THE INVENTION

In rotary tubular kilns, high temperatures are usually used. In order to achieve such high temperatures, the rotating tube can be heated indirectly to the desired temperature with a heating medium, such as hot gas or hot air. Heating may be performed until the interior of the rotating tube reaches the desired temperature, e.g. from about several hundred degrees Celsius up to, in certain applications, greater than one thousand degrees °Celsius, for chemical processes or other desired processes taking place therein.

To this end, the rotating tube is usually surrounded by a heating tunnel, as shown, schematically, in Figure 1. Figure 1 illustrates a schematic cross-section through a rotary tubular kiln, according to the state of the art. The heating tunnel 12 serves as a housing and surrounds the rotating tube 10. The tube 10 turns in the direction of the arrow C, or in the opposite direction. Provided for the tube 10, are several burners 14 extending along its entire length, which indirectly heat the rotating tube, and gas outlets 16. A heating medium, such as hot gas, is introduced through the gas inlets 14A. The medium flows around the circumference of the rotating tube (also called a rotating drum) and thus heats the tube. The gas can flow around both the underside of the rotating tube (as shown by arrow A) as well as the upper side of the rotating tube (as shown by arrow B) .

The efficiency of the kiln is much greater by providing a flow of heating medium along the upper side of the rotating tube. The kiln efficiency is increased because the residence time of the gas along the surface of the rotating tube is increased and thus more time is provided for heat exchange. Moreover, flow of heating medium along the upper side results in exposure of a larger surface fraction of the rotating tube to the flow of heating medium, i.e. hot gas. Since it is possible for a portion of the gas, however, to flow around the underside of the rotating tube, a loss in efficiency occurs. This results since with such a flow pattern, the heat exchange is clearly less. A loss in efficiency and reduction in heat transfer also occurs if a narrow passage is provided in the form of a slit D along the underside of the rotating rube. In this case, the flow of heating medium would move along arrow A'.

The rotating tube in Figure 1 is schematically depicted as being circular. However, in reality, the tube is not exactly circular in cross section. Since such a rotating tube extends over several meters, and in some instances up to 100 m, it is technically almost impossible to guarantee a completely round profile over this entire distance. Furthermore, the rotating tube will also exhibit some degree of imbalance or deviation from its axis of rotation.

Accordingly, there is a need for a rotary tubular kiln having an increased efficiency. Furthermore, there is a need for a device and approach for providing such increased efficiency in view of a typical tube's deviation from having a true circular cross section, and/or from an imbalance or deviation of the tube from its axis during rotation.

SUMMARY OF THE INVENTION

In a first aspect, the present invention provides a rotary tubular kiln comprising a heating tunnel wall that defines an interior heating tunnel. The kiln further comprises an externally heatable, rotatable tube disposed within and generally surrounded by the heating tunnel wall. The rotatable tube defines an outer surface. The kiln also comprises a longitudinal sealing member disposed within the interior heating tunnel. The sealing member extends between the tunnel wall and the outer surface of the rotatable tube. The sealing member is positioned within the interior heating tunnel to thereby

define an entry side and an exit side of the interior heating tunnel. The sealing member includes (i) a rigid portion positioned at a distance from the rotating tube, and (ii) a flexible portion positioned adjacent to the outer surface of the rotating tube.

In yet another aspect, the present invention provides a method for producing a longitudinal sealing member in a rotary tubular kiln. The kiln includes (i) a heating tunnel wall defining an interior heating tunnel, and (ii) a rotatable tube disposed within the interior heating tunnel. The method comprises a step of forming a wall within the interior heating tunnel. The wall extends generally parallel to a longitudinal axis of the tube. And, the wall is formed from a rigid material. The method also comprises a step of providing a plurality of flexible strips. And, the method includes a step of affixing the plurality of flexible strips to the wall such that the strips are positioned adjacent to an outer surface of the tube.

The present invention may take form in various components and arrangements of components, and in various techniques, methods, or procedures and arrangements of steps. The referenced drawings are only for purposes of illustrating preferred embodiments, they are not necessarily to scale, and are not to be construed as limiting the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates an indirectly heated rotary tubular kiln, according to the state of the art, in schematic cross-sectional view.

Figure 2 is a schematic illustration of a preferred embodiment rotary tubular kiln, in accordance with the present invention in vertical view, along line II-II in Figure 4.

Figure 3 illustrates the preferred embodiment rotary tubular kiln, in vertical section, taken along line III-III in Figure 2.

Figure 4 illustrates the preferred embodiment rotary tubular kiln, in horizontal section, taken along line IV-IV in Figure 2.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention relates to a rotary tubular kiln, which provides a more efficient heat exchange with a heating medium. The present invention is

particularly directed to increasing the heat exchange efficiency of a rotary tubular kiln, in view of the characteristics of the rotating tube.

Accordingly, the present invention provides a longitudinal sealing member, preferably extending below the rotating tube, for a rotary tubular kiln, in which a rotating tube is surrounded by a heating tunnel. Use of the sealing member prevents flow of the heating medium around both sides of the rotating tube which would otherwise be in effect, an almost complete thermal short circuit, if not completely. The sealing member includes a rigid portion and a flexible portion.

The flexible portion of the longitudinal sealing member, which preferably is positioned constantly against or in contact with the rotating tube, is able to adapt to or accommodate the imbalance and/or profile change of the rotating tube and thus ensures an essentially impermeable longitudinal sealing of the rotating tube for the heating tunnel wall. Furthermore, this longitudinal sealing configuration has a particularly beneficial effect on the transfer of heat through the rotating tube wall, since the tube wall constantly undergoes a brush-like cleaning by the flexible portion.

Use of the present invention rotary tubular kiln, comprising the noted sealing member reduces the requisite temperature difference between that of the heating medium and the desired interior temperature of the rotating tube, since the resulting heat exchange occurs with a higher efficiency. Thus, there is a savings in energy. Moreover, the rotating tube experiences less thermal load. Use of the present invention enables new opportunities in the selection of the kiln wall material.

The present invention and its components, are not limited to any particular size, shape, material selection, and configuration.

Referring to Figure 2, in accordance with the present invention, a rotary tubular kiln is provided, comprising a rotating tube 30, which can rotate within an approximately bowl-shaped, surrounding, stationary heating tunnel 32. The heating tunnel surrounds the rotating rube, preferably along a substantial portion of the length of the heating tunnel. The heating tunnel wall 32A defines at least one inlet 34 for a heating medium such as hot air or hot gas, and at least one outlet 36. The inlet and outlet are, as shown in Figure 4, and in this respect, preferably shaped as relatively long recesses or openings of

the heating tunnel, and arranged on the side walls that form the tunnel. The inlet and outlet can also be in the form of connections or tubes provided in a tunnel wall.

Usually, the rotating tube receives a flow of heating medium along its circumference and its entire length. The essential direction of flow of the heating medium is thereby in the direction of flow arrows B—that is, generally perpendicular to the rotating tube axis. However, it will be understood that heating can occur from flow of the heating medium in a direction that is generally the same as, or opposite to, or both, as compared to the direction of rotation of the tube.

Usually, the heating tunnel 32, defined as the region between the tunnel wall 32A and the rotating tube 30, is sealed off with respect to at least the front side of the kiln, in order to prevent an escape of the heating medium except through the outlet 36. The rotating tube can be completely surrounded by the heating tunnel or also laterally project over the heating tunnel.

The longitudinal sealing member 20 is preferably disposed as a separation wall between the entry side 38 and the exit side 40 of the heating tunnel 32. The longitudinal sealing member 20 comprises a rigid portion 22 and a flexible portion 24. In one embodiment, the longitudinal sealing member 20 includes a flat, long wall with one or more flexible sealing elements disposed thereon. The wall preferably extends along the entire length of the heating tunnel 32 and joins the front walls 32B of the same, as can be seen from Figure 3 and Figure 4. Thus, flow of the heating medium along the front side of the longitudinal sealing member is prevented. In some applications, the wall may only extend along a portion of the length of the heating tunnel 32.

As shown in Figure 2, the longitudinal sealing member 20 in a preferred embodiment can have a width of approximately 10% to about 20% of the diameter of the rotating tube. The width of the longitudinal sealing member, however, can also be selected to be smaller or larger, depending on the requirement or specific application.

The rigid portion 22 of the sealing member preferably includes a region of brick. However, any other rigid or refractory material, which withstands the temperatures that exist in the heating tunnel can be utilized. As indicated in

Figure 2, the rigid portion 22 can extend near the rotating tube 30 so long as the portion is not seized by the tube during rotation of the tube. In building the rigid portion, it is advisable to appreciate that the rotating tube in most instances, will not rotate precisely during the operation of the kiln because of the previously described lack of precision in the rotating tube profile and because of imbalances or deviations in rotation of the tube about its axis.

The flexible portion 24 of the sealing member is preferably disposed on the rotating tube-side end of the rigid portion 22. That is, the flexible portion is preferably located on or at the distal end region of the rigid portion, closest to the rotating tube. The flexible portion is preferably made of a material which is sufficiently flexible so that the portion 24 can contact and readily adapt to the inaccuracies of the rotating tube profile during rotation of the rotating tube. Moreover, the flexible portion should withstand the temperatures which exist within the heating tunnel. Preferably, the flexible portion is formed from a material comprising a majority of ceramic fibers.

Figures 3 and 4 show various views of the preferred longitudinal sealing member and its incorporation in the heating tunnel. As can be seen from these figures, the flexible portion preferably includes strips and/or strip packets of a flexible material joined to one another. The strips and/or strip packets are preferably positioned at a right angle to the rotating tube axis. This configuration requires a certain minimum thickness of the longitudinal sealing member 20. This arrangement ensures, on the one hand, an improved sealing and, on the other hand, a higher service life of the sealing. To increase the tightness or degree of sealing, the individual strips and/or strip packets can also be cemented with one another or otherwise affixed to one another. The flexible portion 24 is preferably produced by pressing individual strips and/or strip packets between the rigid portion 22 and the rotating tube 30 (see Figure 2). Depending on the particular application, the flexible portion is connected with the rigid portion 22, as, for example, by cementing. As particularly preferred, the individual strips and/or strip packets are compressed vertically and in their stacking direction. This ensures that the sealing member functions satisfactorily even after long operation and corresponding wear. Furthermore, this prevents individual parts or portions of

the longitudinal sealing member from being removed from their specific position by the rotating movement of the tube.

As shown in Figure 4 and in this respect as a preferred embodiment, several burners 34 can be positioned opposite a single gas outlet 36. In this configuration, the direction of flow of the heating medium, which escapes from the burner 34C, at a distance from the gas outlet, will occur not only along the circumference of the rotating tube but rather also diagonally, in the direction of the gas outlet 36. A preferred longitudinal sealing member, in accordance with the present invention, has a particularly favorable effect in this configuration. A substantial part of the heating medium will then flow around the rotating tube at least until the medium reaches the upper side of the rotating tube, instead of immediately being suctioned in the direction of the gas outlet 36 because of the diagonal flow.

In a preferred embodiment, the strip packet includes 25 mm-thick ceramic fiber mats which are at least 75 mm high and approximately 34.5 cm wide (KT 1430°C; RG about 200 kg per square meter), which are compressed to 20 mm. In certain applications, the strips may be formed from an elastic and compressible material. If desired, several strips can also be pressed in, as strip packets, above one another, between the rigid portion 22 and the rotating tube 30. By pressing, it is possible to influence the flexibility of the flexible portion 24. It is also possible to first place a somewhat less flexible ply on the rigid portion 22 and then place on it, in turn, a more flexible material. In the same way, the rigid portion 22 can also include several plies or layers of different materials, on and/or next to one another.

However, it may also be desired for several strips, which are positioned next to one another and are made of a flexible material, to extend parallel to the longitudinal sealing wall. This is particularly advantageous if the flexible portion on the inlet side of the heating tunnel is to exhibit other material characteristics than on the outlet side—for example, because of the different temperatures. In this case, the pressing-in process would have to be correspondingly modified. Here, too, several plies of flexible material would have to be taken into consideration.

The flexible portion is adaptable to the rotating tube outer surface in that the flexible portion 24 is preferably produced by pressing strips and/or

strip packets between the rigid portion 22 and the rotating tube 30. Thus, inaccuracies and/or fluctuations in the rotating tube profile can be accommodated, for example, if a rotating tube has, at one site, a somewhat greater outside diameter, perhaps due to a welding seam or something similar.

List of reference symbols

10	Rotating tube
12	Heating tunnel
14	Burner
14A	Inlet
16	Outlet
20	Longitudinal sealing member
22	Rigid portion
24	Flexible portion
30	Rotating tube
32	Heating tunnel
32A	Heating tunnel wall
32B	Heating tunnel front wall
34	Burner
34A	Inlet
34C	Burner
36	Outlet
38	Entry side of the heating medium
40	Exit side of the heating medium
A	Flow arrow
A'	Flow arrow
B	Flow arrow
C	Rotation direction
D	Slit

The exemplary embodiment has been described with reference to the preferred embodiments. Obviously, modifications and alterations will occur to others upon reading and understanding the preceding detailed description. It is intended that the exemplary embodiment be construed as including all such modifications and alterations insofar as they come within the scope of the appended claims or the equivalents thereof.